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TITLE: METHOD FOR FORMING CONDUCTIVE BUMPS FOR THE PURPOSE OF CONTRRUCTING A FINE PITCH TEST DEVICE

6,064,217, 5,475, 317

Pre-Grant Publication (PGPub) Document Number (1):
20020011859Summary of Invention Paragraph (6):

[0005] Thus, there is a need to certify that each individual die is a "known good die" prior to packaging the die within the MCM. Some prior art references describe attempts to produce a known good die by first packaging the die, conducting tests at various temperatures, subjecting the integrated circuit to "burn-in" at elevated temperature, recovering the die by destroying the packaging to remove the die and then placing it within the hybrid circuit or MCM. Such a process is labor intensive and expensive and still could result in uncertainty in determining whether a die is a "known good die." Thus, there is a need for a device and method for testing bare die which allow bare die to be tested in a more cost effective manner.

Summary of Invention Paragraph (7):

[0006] Other prior art references disclose various probe cards which test the die while on the wafer. Some prior art references, such as U.S. Pat. No. 5,103,557 issued to Leedy, disclose performing tests before the metallization layers are added to the individual die still contained on the semiconductor wafer. These tests, however, only certify that a die is good at this stage in its manufacturing cycle. The completely manufactured die is not tested. It is important to test the completely manufactured die because defects can be introduced, not only when the metallization layers are added, but also when the die is separated from the semiconductor wafer.

Summary of Invention Paragraph (8):

[0007] A problem with the above device and test methods is the utilization of rigid metal probes or probes with rigid metal tips for establishing electrical continuity. Such probes are difficult to manufacture and require high maintenance. Because the individual probes are so minute, the practical difficulties of using probe cards include keeping the probes straight, keeping them at an even or planar height, and establishing electrical contact through all of the probes in the proper location simultaneously without exerting so much pressure on the semiconductor wafer that it is damaged. Additionally, the mere act of establishing electrical contact with the proper points within a circuit can be a challenging task. Frequently, special lenses or cameras are required to accomplish this task. Thus, there is a need for a device which allows the task of connecting test equipment to the die to be routine, simple and quick.

Summary of Invention Paragraph (9):

[0008] Another problem with using probe cards as disclosed by Leedy is that they typically have inherent frequency response characteristics which inhibit full functional testing of an integrated circuit throughout the desired frequency ranges. Further, these types of probe cards are designed to contact a die while it is still an integral part of the entire semiconductor wafer. They are not intended for testing bare singulated die. Thus, the cards cannot be used to test the overall reliability of the bare die to determine whether the die will work for a significant

duration of time. Neither do they provide a means for testing the die over a broad range of temperatures.

Summary of Invention Paragraph (10):

[0009] Other prior art references, such as European patent No. 554,622 issued to Pedder, disclose the use of a test socket in connection with a test station wherein the interface between the bare singulated die and the test socket is a plurality of conductive microbumps soldered onto the test socket contact pads. A problem with such a device is that it is very difficult to manufacture bumps such that pad to bump contact is established for all die bond pads because of the rigidity of the solder microbumps. In other words, use of such bumps introduces planarity problems. Furthermore, the use of such bumps does not insure solid and continuous electrical contact with the bare die bond pads. Additionally, the frequency bandwidth is limited. Thus, these metal bumps do not support all of the types of required tests which may have to be performed even if they do successfully establish electrical continuity with the die bond pads.

Summary of Invention Paragraph (11):

[0010] Other disclosures utilize a polyimide film upon which metallic microbumps are placed. For example, see Aehr Test, Nitto Denko Develop KGD Solution, Electronics Packaging & Production, September 1993, at 11-12. The article discloses a plurality of gold or nickel plated bumps on polyimide film with a proprietary hole-making technology which connects the bond pads of a die to the pads of a substrate. The use of such a carrier allows for interfacing a bare die to a burn-in board and for conducting burn-in tests. One problem with such an implementation is the difficulty of plating the small microbumps; the disclosure does not adequately disclose the method of plating the microbumps. A second technical problem is the establishing of electrical continuity between the plated bumps and the pads of a substrate or test socket. In fact, in this disclosure, it is clear that this connection means involves the use of a proprietary technology that is not generally available to the public. A third technical problem is damage caused by rigid bumps to die bond pads during temperature excursions typically occurring during high temperature test and burn-in. Finally, this method does not completely solve the previously discussed planarity problem. While the polyimide film establishes some give and take, which helps alleviate the planarity problem, high precision and consistency is still required in order to build a plurality of microbumps, each of which must be sufficiently close to the same plane to establish electrical continuity with the bond pads of the bare die. This occurs because the range of flexible movement resulting from the use of a polyimide film carrying a rigid contact or probe is small. Furthermore, such devices have been known to limit the frequency bandwidth and therefore the types of test and burn-in procedures that can be run or executed.

Summary of Invention Paragraph (12):

[0011] Other methods of testing bare die include the permanent addition of interface circuitry to the bare die; circuitry which allows the die to be interfaced to a burn-in board. Obvious disadvantages include the increased size and weight of the die packaging. Further, such a solution significantly increases the labor and material costs of testing a bare die. To solve the increased weight and size problem, other disclosures have included the final step of removing or peeling away the added packaging. A well recognized disadvantage of this solution is that the bare die bond pads are frequently damaged as discussed by Falconer and Lippold, A Survey of Techniques for Producing Known Good Die, ISHM-Nordic 31st Annual Conference, at 3 (1993).

Summary of Invention Paragraph (13):

[0012] Because of the low yield rates of MCMs and because testing singulated bare die has heretofore not been economically feasible or technically acceptable, the costs of MCMs have been high when compared to the creation of circuits comprised of the combination of individual integrated circuits which contain the same die as the MCM. Thus, the MCM manufacturing industry has been suppressed relative to the demand for such a product in part because of the high cost of MCMs. Unless a particular design requires minimization of space and power consumption, the high cost of an MCM is not justified. Therefore, up until now, a need has existed to create an apparatus and method of cost effectively testing bare singulated die to produce "known good die" for inclusion in multi-chip modules.

Summary of Invention Paragraph (14):

[0013] In addition to there being a need for contacting and testing bare singulated die, there is also a need for contacting and testing other unpackaged fine pitch devices such as semiconductor wafers, packaged semiconductor devices such as micro ball grid arrays and chip-scale packages as well as apparatus for testing or carrying semiconductor devices including probe cards, bare printed circuit boards, and populated circuit boards.

Summary of Invention Paragraph (15):

[0014] The basic problem encountered during testing each of the fine pitch devices listed including bare die is related to the ability to contact the contact points given their size and quantity on a typical device. Additionally, the problem continues to become more challenging. Electronic device manufacturing firms continue to push the miniaturization of electronic packaging technologies. For example, low cost quad flat packs are being made continuously thinner and with smaller profile packages. Examples of some of the thinner and smaller packages are the thin quad flat packs ("TQFP") and tape-automated bonding ("TAB") packages. Discrete component packages of capacitors, resistors, and inductors are expected to shrink at least another twenty percent in size. Printed circuit boards and other devices are also continuing to shrink. Some experts believe that the current limit of 0.4 mm pitch in surface mount technology applications will soon be reduced to 0.15 mm pitch.

Summary of Invention Paragraph (16):

[0015] The trend towards finer pin pitch and package miniaturization is clearly creating new problems and needs in terms of contact and test technology. These current trends will be stymied unless a new technology for contacting the ever increasing number of contact points per square inch and ever decreasing contact point size can be developed successfully so that fine pitch devices may be tested properly at ambient temperature as well as elevated and lowered temperatures, if necessary.

Summary of Invention Paragraph (18):

[0017] It is known that all of these new technologies require advancements in substrate technology as well as in burn-in and test techniques. The smallest possible package is no package at all or a bare die. It is known, however, that the use of bare die has been thwarted by their dependence on a viable supply of known good die. More generally, however, the development of all of these types of packaging technologies rely upon development of devices and methods for testing and contacting these increasingly smaller contact points which are continuously increasing in density.

Summary of Invention Paragraph (19):

[0018] The problem of contacting so many small contact points for these listed devices is the same problem encountered for testing bare die, namely, establishing a solid conductive contact adequate even for burn-in testing in a manner that does not require some sort of bonding to the device being tested.

Summary of Invention Paragraph (21):

[0019] The invention solves the shortcomings of the prior art by disclosing a reusable carrier system for testing fine pitch devices, and more particularly, bare singulated semiconductor die, semiconductor wafers, packaged semiconductor devices, chip-scale packages, and circuitry for testing or carrying semiconductor devices including probe cards, bare printed circuit boards, populated circuit boards, ball grid arrays and chip-scale packages. The reusable test carrier utilizes electrically conductive elastomeric bumps (hereinafter, "elastomeric probes") in lieu of rigid metallic probes or solder balls. The conductive elastomeric probes are permanently applied to an electrically conductive circuit pad pattern of a test carrier whose circuit pad layout is based upon the layout of the contact point pattern of the fine pitch device to be tested. Then, the adhesive quality of the probe is rendered in-adhesive through a curing process. Curing the probes in this manner allows the probes to make repetitive and temporary contact with the device being tested or contacted.

Summary of Invention Paragraph (22):

[0020] An important element in establishing electrical continuity between the pads of the test carrier and the corresponding contact points of the fine pitch device is the placement of the device being tested or contacted such that contact points are aligned and in electrical contact with the electrically conductive elastomeric probes. As can be appreciated by those skilled in the art that such contacting between two components would be useful for a variety of purposes. For example, the repetitive contacting may be employed for the transfer of data or energy. Repetitive and temporary contacting may also be used for collecting data or measurement-related data during the transfer from one component to the other. Further, coupled with precise alignment, it should be understood upon reference hereto that contacting could be used for effecting at least part of an identification scheme or process (e.g., electrical/mechanical pattern recognition) using one of the components as a template.

Summary of Invention Paragraph (23):

[0021] The alignment problem has been solved by the utilization of an alignment template. An alignment template consists of a board made out of printed circuit board material, or ceramic, or the like, with an aperture or hole which is approximately the size and shape of the perimeter of the device being tested. The aperture is located within the alignment template such that the placement of the device within the aperture or hole forces the corresponding pads and contact points of the device to properly align.

Summary of Invention Paragraph (24):

[0022] A second embodiment for solving the alignment problem contains a number of strips or posts of a hard material that are permanently placed on the surface of the test carrier such that the shape defined by the internal points of the strips or posts approximately defines the perimeter of the die or device being tested. Like the alignment template, proper alignment of the corresponding bond pads of the die or contact points of the device being tested and the circuit pads of the test carrier occurs when the die or device being tested is placed within the arrangement of strips or posts.

Summary of Invention Paragraph (25):

[0023] Alternatively, the strips or ports are placed to mate with the device being tested in a manner that directs the alignment of the devices. For example, the device may contain apertures formed to mate with the strips or points whenever the device is properly aligned.

Summary of Invention Paragraph (26):

[0024] Another embodiment for solving the alignment problem involves using robotics to align and place the die or device being tested onto the die carrier or test socket.

Summary of Invention Paragraph (28):

[0026] The method for testing includes, if necessary, removing oxidation from the bond pads or contact points of the device being tested prior to placing the device being tested within the carrier and into electrical continuity with the test equipment. The natural build up of oxidation on the bond pads of die, for example, has been found to interfere with test results to the point that a good die could feasibly be misdiagnosed as being defective. In a further aspect, the method of the present invention uses the urging of the elastomeric probes against the die bond pads. It can be appreciated that the urging can break through the natural oxidation on the bond pads and electrical continuity can be established. The method of testing the bare die or fine pitch device also includes pushing and securing the die or fine pitch device against the conductive elastomeric probes of the carrier until electrical continuity is established between each bond pad of the die or contact point of the fine pitch device being tested and its corresponding elastomeric probe.

Summary of Invention Paragraph (30):

[0028] Regarding bare die and other devices needing burn-in certification or testing, there is a need for ascertaining that the die or device is in continuous electrical communication with the circuit or mother board during what is commonly known as "burn-in" testing. Burn-in testing usually occurs within an oven or

chamber, and involves continuously operating the device being tested under extreme or at least increased temperature conditions. In ordinary circumstances, confidence in established art usually eliminates the need to continuously monitor or verify electrical continuity while the device is being operated in a burn-in board test circuit. However, because this invention utilizes packaging that is used on a temporary basis, continuous electrical continuity cannot be assumed. Thus, the invention discloses a method for verifying electrical continuity. Specifically, the method is to continuously or nearly continuously obtain data or measure electrical voltages from the die by connecting appropriate cables between the burn-in board and test and measurement devices during the burn-in process. A reading of nonexpected value would then indicate either failure of the die or a break in electrical continuity.

Summary of Invention Paragraph (31):

[0029] Additionally, the method for testing includes a means of lowering or elevating the temperature of the die or semiconductor device under test (DUT) by conductive heat transfer to or from the DUT by placing a thermoelectric cooler (TEC) in thermal contact with the die. Use of the TEC is preferred in lieu of current methods of convective heat transfer using conventional forced air temperature forcing devices.

Summary of Invention Paragraph (32):

[0030] The elastomeric conductive probes and the alignment template or posts primarily accomplish the overall object of this invention which is to provide an apparatus and method for testing bare singulated die and other fine pitch devices that greatly reduce the cost of such tests and which makes testing of certain products or devices possible.

Summary of Invention Paragraph (33):

[0031] The method for testing fine pitch devices, and more specifically, semiconductor wafers, includes placing the wafer within the carrier and performing wafer level burn-in test. For each die which is identified as being defective during the wafer level burn-in test, a "map" is created to track which die on the semiconductor wafer have failed either while being exercised during burn-in or prior to burn-in test. Thereafter, the individual bare die are diced from the semiconductor wafer after which further testing of bare die not known to be failed, as indicated by the map, may be performed. Completion of the final testing leads to the conclusion as to whether a bare die is a known good die and can be packaged either individually or in a multichip module.

Brief Description of Drawings Paragraph (7):

[0037] FIG. 6 shows a die clamp for room temperature or oven testing and a die carrier with a carrier connector.

Brief Description of Drawings Paragraph (8):

[0038] FIG. 7 shows a cutaway view of a carrier for testing fine pitch devices.

Detail Description Paragraph (2):

[0040] The present invention, in all of its embodiments, solves deficiencies of the prior art to achieve testing of a bare singulated die and other fine pitch devices by creating a carrier which is designed to hold a fine pitch device and to establish electrical continuity with the contact points of the fine pitch devices. These deficiencies are primarily solved by the utilization of electrically conductive elastomeric probes to contact the contact points of the fine pitch device, by way of example, the bond pads of a die, an alignment template to position the fine pitch device, and an overall configuration which allows for repetitive and labor efficient use of the carrier. Furthermore, some fine pitch devices, by way of example, a bare die, can be held in place throughout testing. This allows the bare die to be tested and certified for all required temperatures. The specific tests conducted vary and are determined by the complexity of the bare die and by the certification requirements for the die. One skilled in the art can readily determine what types of test procedures are appropriate and can use this disclosure to perform the tests. Nonetheless, the specific apparatus and test procedures used by this inventor are also disclosed.

Detail Description Paragraph (3):

[0041] Referring now to FIG. 1, there is shown a cutaway view of a die carrier in a conventional socket configuration. As is seen in FIG. 1, electrical contact between the circuit pads 4b of a die carrier 4 and the bond pads 2a of a bare die 2 occurs through the elastomeric probes 4a. Specifically, die carrier 4 contains a plurality of circuit pads 4b which are arranged to correspond with the bond pads 2a of the bare die 2 such that the bond pads 2a of the bare die 2 line up directly over the circuit pads 4b of the die carrier 4 when the bare die 2 is properly positioned over the die carrier 4. The method of placing the circuit pads 4b on the surface of the die carrier 4 is old and well known in the art. The conductive elastomeric probes 4a are permanently placed upon circuit pads 4b, wherein the elastomeric probes 4a have been designed to continuously and repetitively establish electrical continuity between it and either bond pads 2a of different die 2, or any other type of electrically conductive probe or lead including other elastomeric probes. Specifically, after the probes are placed onto the circuit pads 4b, they are cured to establish a resilient non-adhesive surface to support repetitive contacts with other conductors. It is not a requirement that every bond pad 2a on the die 2 have a corresponding circuit pad 4b on the die carrier 4. The only circuit pads 4b required on the die carrier 4 are the ones through which electrical signals are to be applied and/or measured during testing. However, for the sake of simplicity and engineering economy, the preferred embodiment includes a pad pattern on the die carrier 4 which is a mirror image of the bond pad pattern of the bare die 2. Moreover, the shape or size of the circuit pad may be varied so long as permanent contact may be established with the electrically conductive elastomeric probe of the carrier.

Detail Description Paragraph (5):

[0043] The composition of the elastomeric probes is not significant so long as the elastomeric probes 4a meet certain performance criteria. The performance criteria for testing bare die include: (1) the elastomer must be able to withstand wide ranges of temperature, the minimum sustained temperature being minus 55.degree. Celsius and the maximum temperature being plus 125.degree. Celsius (in the event Military certification is desired); (2) the elastomeric probes 4a must be somewhat malleable in texture; and (3) the elastomeric probes 4a must provide a low throughput resistance over a wide frequency range and must be able to freely conduct electricity as a result of being doped with a proper conductive doping agent as is known by those skilled in the art. If this disclosed device is to be used to test other fine pitch devices or discretes, then the requirements may change. For instance, one military certification standard requires the minimum sustained temperature to be minus 65.degree. Celsius and maximum sustained temperature to be plus 175.degree. Celsius. Such changes are intended to be a part of the disclosed invention. Furthermore, it is important that the elastomeric probes 4a be able to maintain their properties through multiple uses. The composition of acceptable elastomers include, but are not limited to, polyepoxides, polystyrenes, polyimides and other elastomeric polymers and epoxies. The preferred material is an electrically conductive epoxy resin. Proper doping agents to impart electrical conductivity to the resins include tungsten, gold, copper and silver. The preferred doping agent is silver which has been used to render adhesives electrically conducting as described in U.S. Pat. No. 5,196,371 and U.S. Pat. No. 5,237,130, both being issued to Kulesza et al, incorporated herein for all purposes. However, the concept of utilizing conductive polymers can be manifested in other similar and undeveloped compounds or with other doping agents not mentioned herein and is an intended part of the invention.

Detail Description Paragraph (6):

[0044] There are at least three means for orienting the bare semiconductor die 2 onto the elastomeric probes 4a which are permanently mounted upon the circuit pads 4b of the die carrier 4. FIG. 2 shows one means for orienting; namely, an alignment template 6. The alignment template 6 is permanently mounted onto the die carrier 4 (as is also shown in FIGS. 1, 3, 5 and 6). Referring again to FIG. 2, the alignment template 6 contains an aperture 8 corresponding to the size and shape of the bare die 2 being tested. This alignment template 6 is designed to receive the bare die 2 and to orient the bond pad 2a pattern of the die 2 into alignment with the corresponding electrically conductive elastomeric probes 4a of the die carrier 4.

Detail Description Paragraph (9):

[0047] In another embodiment of the means for orienting the die in position for testing, small and firm protrusions placed to define the area in which a bare die 2 is to be placed, herein "guidance points 9", are permanently mounted onto the die carrier 4. Referring to FIG. 4, the bare die 2 (not shown) fits within the pattern of guidance points 9 such that the bond pads 2a of bare die 2 (not shown) contact the elastomeric probes 4a of the die carrier 4 whenever the die 2 is placed within the pattern of guidance points 9. It is helpful to visualize the arrangement of these guidance points 9 as a series of fence posts which define the perimeter of the shape of the die wherein the die 2 fits exactly within this perimeter of guidance points 9. FIG. 4 illustrates a top view of this relationship between the arrangement of circuit pads 4b of a die carrier 4 and an arrangement of guidance points 9. Note that not all of the circuit pads 4b contain a conductive elastomeric probe 4a. The only requirement is that, at a minimum, the circuit pads 4b through which electrical signals must be supplied or monitored will contain elastomeric probes 4a. However, for other reasons, a practitioner can determine if it is desirable to have additional elastomeric probes. For example, requirements of structural support or engineering economy may encourage the utilization of "extra" probes 4a.

Detail Description Paragraph (10):

[0048] In another embodiment of the means for orienting, a robotic device (not shown), i.e., a computer controlled mechanical arm, is used to pick up the die 2 from an input tray or "waffle pack" (not shown), place it onto the die carrier 4 with high precision, and to hold the bare die 2, onto the elastomeric bumps 4a of the die carrier 4 such that the die bond pads 2a maintain electrical continuity with the circuit pads 4b of the carrier 4. To establish this electrical continuity, the robot arm (not shown) not only orients the die 2 such that the die bond pads 2a are in communication alignment with the circuit pads 4a of the die carrier, but also pushes or forces the die 2 at least to the point that the bond pads 2a are in firm and electrical contact with the electrically conductive elastomeric probes 4b. The robotic mechanism is programmed to place the die 2 repeatably and with great accuracy, thereby providing for a higher rate of handling than with manual placement. To aid in placement accuracy, optical alignment may be used with the robotic mechanism. The robotic mechanism also can remove the tested die 2 from the carrier 4 and place it in the appropriate output tray or waffle pack, separating good die 2 from failures. The obvious advantage of this embodiment is that it is oriented for assembly line style testing with low overhead labor costs.

Detail Description Paragraph (11):

[0049] There are at least three embodiments for the means for connecting the die to a given test instrument. One embodiment is seen in FIG. 1 where the means for connecting is standard circuit wiring which electrically connects the circuit pads 4b of the die carrier 4 to its leads 5. Each circuit pad 4b of the die carrier 4 will be connected to at least one lead 5 of the die carrier 4.

Detail Description Paragraph (13):

[0051] However, there may be leads 5 on the die carrier 4 which are unconnected to the circuit pads 4b. The exact arrangement or electrical interconnection between the circuit pads 4b and the leads 5 is a function of the number of bond pads 2a of the die 2 to which electrical continuity must be established for the purposes of testing. Because such arrangements will vary widely according to the particular die 2 being testing in relation to the test requirements for that die 2, the specific arrangement cannot be specified herein. However, one skilled in the art can readily ascertain without undue experimentation what the interconnect scheme should be.

Detail Description Paragraph (17):

[0055] Referring again to FIG. 2, the ceramic spacer 7a is designed to be placed between the alignment template 6 and a socket lid 7 (as shown in FIG. 1) of a production socket (not shown) which houses the die carrier 4, the alignment template 6 and the bare die 2. The purpose of the spacer is to urge the die against the elastomeric probes 4a. However, the spacer and production socket (not shown) are designed so that thermoelectric cooler (TEC) 30 (as is shown in FIG. 5) can be substituted for the spacer 7a to allow for testing at temperatures above or below ambient.

Detail Description Paragraph (18):

[0056] Referring to FIG. 5, the preferred mechanical and physical relationships between an auxiliary cooling heat exchanger 24, a thermoelectric cooler 30, a bare die 2, a die carrier 4 and surface mounted carrier connector 12, in a surface mount socket configuration are shown. The TEC 30 is placed adjacent to and is urged into direct contact with the bare die 2. Furthermore, an auxiliary cooling heat exchanger 24 is urged against the hot side of the TEC 30. This configuration is used whenever the die 2 must be tested at non-room temperatures, or when it is necessary to overcome internal heating of the bare die 2. Such a configuration will support the range of temperatures required for all known certification procedures including military certification for the bare die 2. Specifically, military certification requires that the die be operationally certified at minus 55.degree. Celsius as well as at plus 125.degree. Celsius. If this configuration is used for testing discrete components or other devices, a practitioner should insure that its TEC is capable of supporting the rigid temperature range.

Detail Description Paragraph (19):

[0057] There are various methods which can be used for heating and cooling the die 2 during testing at extended temperatures. One method includes placing the die 2 and a die carrier 4 within the heating/cooling chamber of a temperature forcing unit (not shown) of some sort.

Detail Description Paragraph (20):

[0058] Heating and cooling chambers (not shown), however, take significantly longer than a TEC/auxiliary cooler to raise or lower the die temperature. A TEC 30, as is shown in FIG. 5, raises or lowers the temperature of the die 2 rapidly, owing to the use of conductive rather than convective heat transfer. The use of such a system greatly reduces overall test time and therefore, cost of performing the test. For instance, the use of a convective temperature forcing device such as a conventional oven (not shown) can take several times as long for the die 2 to reach the desired temperature. The method of using the thermoelectric cooler/heater is well known in the art and can be readily determined from the vendors of such devices.

Detail Description Paragraph (22):

[0060] Referring to FIG. 6, the clamp 20 supports "burn-in" testing in a conventional oven. Clamp 20, which is attached to the die carrier 4, will hold the die 2 in place such that the bond pads 2a of the die 2 maintain electrical continuity with the electrically conductive elastomeric probes 4a which are permanently attached to the circuit pads 4b of the die carrier 4. To use the clamp 20 of FIG. 6, one merely places the die 2 within the aperture 8 as shown in FIG. 2, of the alignment template 6 and then one turns the knob 20d in a clockwise manner. The bolt 20b will rotate in a downward manner through clamp plate 20a thereby forcing clamp press 20c in a downward manner to urge the bare die 2 against the electrically conductive elastomeric bumps 4a. Note that a production socket (not shown) could accomplish the same task if ceramic spacer 7a is placed within the socket. Because the die carrier 4 is electrically connected with the carrier connector 10, the carrier connector 10 may be plugged into a burn-in board 14 (shown in FIG. 5) for the continuous "burn-in" testing process. The burn-in board 14, in turn, is connected to various pieces of test equipment through standard wiring in a manner well understood by those skilled in the art.

Detail Description Paragraph (23):

[0061] Historically, die 2 have been "burned in" after being packaged. Because electrical contacts with the external leads of the package can be reliably maintained, there is little reason to be concerned that electrical continuity will be lost during the burn-in process of a packaged die. However, since this single bare die 2 is not permanently packaged, continuous electrical contact during burn-in can no longer be assumed. Therefore, the method of burn-in for the bare die 2 may include continuous or periodic electronic data sampling to insure that electrical continuity is maintained. Once a die 2 successfully completes "burn-in" and post burn-in electrical tests, then that die 2 may be labeled or certified as a "known good die".

Detail Description Paragraph (24):

[0062] While "burn-in" is a term of art which varies significantly within the electronics industry, the inventor's burn-in process, as it relates to bare

semiconductor die, is as follows: Initially, the die 2 is placed within a production socket (not shown) or within a die clamp 20 as is shown in FIG. 6 for pre-burn-in electrical testing. Once the die 2 is within a production socket (not shown) or a die clamp 20, it is connected to a piece of electrical test equipment for comprehensive functional testing of the die. In other words, the die is tested to the point that a practitioner can determine, in all probability, that each of the die's capabilities or functions works properly. Alternatively, the die 2 could be placed within a die carrier 4 that is thermally connected to a TEC 30, as is shown in FIG. 5, and then be comprehensively tested and exercised at an increased or decreased temperature. An advantage to performing a pre-burn-in test at a raised (or lowered) temperature is that a defective die is more likely to fail. Obviously, money is saved by identifying defective die as quickly as possible. The practitioner may utilize any type of production socket so long as it can house a die carrier 4 and an alignment template 6. In order to fully practice the invention as described herein, the production socket must also be able to house a spacer 7a sized to define the same geometric volume of space as defined by a thermoelectric cooler 30. One skilled in the art can readily determine the specific design of such a socket in order to practice this invention in a production environment.

Detail Description Paragraph (25):

[0063] Once a die successfully completes the pre-burn-in electrical test, whether at room or elevated temperatures, the die 2 and die carrier 4, whether in a production socket (not shown) or within a die clamp 20, are connected to a burn-in board 14 and then placed into an oven (not shown) and kept at a raised temperature for a length of time according to test or certification specifications. The inventor's preferred pre-burn-in method tests the die at elevated temperatures. However, other test procedures may require lowered temperatures. One example of a burn-in procedure would be to operate the die 2 through the burn-in board 14 within an oven at 125.degree. Celsius for a minimum of 24 hours. For some applications, the die 2 may be kept in the oven for as many as 168 hours (or longer for other devices). The time that the die 2 is kept in the oven, as well as the oven temperature, is determined by the certification standard being followed for the particular die.

Detail Description Paragraph (26):

[0064] While the die 2 is within the oven, the die is "exercised" or operated at a level less than or equal to its full functional capability. Further, the operation may be monitored repetitively to insure the die 2 has successfully operated and that electrical continuity has been maintained during the burn-in process. Because the die 2 is housed in temporary packaging and continuous electrical continuity cannot be assumed, a given output signal or contents of a data register may be repetitively checked to verify that new or fresh signals or data are being introduced into the die and that the die 2 is satisfactorily processing the signals or data. Finally, it should be noted that these burn-in procedures could be carried out with a thermoelectric cooler instead of in an oven. As a practical matter, however, burn-in testing in an oven allows for a greater number of die to be "burned in" simultaneously and is therefore preferred.

Detail Description Paragraph (27):

[0065] After burn-in, post burn-in electrical tests are conducted. Post burn-in electrical testing includes electrically testing the die 2 at 25.degree. Celsius (ambient or room temperature), then at a high temperature, up to (+) 125.degree. Celsius, and finally at a low temperature, which can be as low as (-) 55.degree. Celsius. Again, the desired temperatures and the length of time for the comprehensive electrical testing are a function of the certification standard being applied to the specific die 2. Use of the thermoelectric cooler 30 for the post burn-in tests greatly expedites the test procedures because the thermoelectric cooler, in conjunction with an auxiliary cooling heat exchanger 24, greatly reduces the time necessary to raise and lower the temperature of the bare die 2, within approximately one minute. Further, this series of tests at the various temperatures can be performed without having to physically move or reconnect the die to any other equipment.

Detail Description Paragraph (29):

[0067] Referring now to FIG. 7, there is shown yet another embodiment of the invention wherein the test socket 100 is adapted for testing fine pitch devices

including semiconductor wafers. Similar to the bare die test socket of FIGS. 1-6, the test socket 100 is adapted to receive the fine pitch device 30, which fine pitch device 30 is comprised of a plurality of contact points 32, which contact points 32 are contacted by the conductive elastomeric probes 34 of the test socket 100. As with the test socket of FIGS. 1-6 for the bare die 2, the malleable and electrically conductive elastomeric probes 34 are printed by conventional means (e.g., as practiced by Epoxy Technology of Boston, Mass.) onto circuit pads 36 in one embodiment of the invention, which circuit pads 36 are a part of the carrier 38. Moreover, as may be seen for the embodiment of FIG. 7, the carrier 38 further comprises connection pads 40 at the bottom of the carrier 38 wherein the circuit pads 36 are connected to the connection pads 40 by the traces 42.

Detail Description Paragraph (30):

[0068] To complete the circuitry, the test socket 100 of FIG. 7 also comprises a carrier connector 44, which carrier connector 44 is comprised of connector leads 46 which are adapted for electrically contacting the connection pads 40 of the carrier 38. As also may be seen, the carrier connector 44 comprises traces 48 which connect the connector leads 46 to external circuitry (not shown). Moreover, as may be seen, the test socket 100 is mounted directly onto a high temperature printed circuit board 90.

Detail Description Paragraph (31):

[0069] Continuing to examine the test socket 100 of FIG. 7, the test socket 100 is comprised of a plurality of the walls 110 which form an aperture 120 through which the fine pitch device 30 is placed to contact the elastomeric probes 34 of carrier 38. As with the test sockets of FIG. 1-6 for testing the bare die 2, it is important to have proper alignment of the contact points 32 of the fine pitch device 30 with the probes 34 of the test socket 100. Accordingly, and for alignment to occur, the fine pitch device 30 is urged in a downward direction as indicated by the arrows 60 through an alignment template 70 wherein proper alignment exists between the contact points 32 and the carrier 38. More specifically, the contact points 32 must align with the probes 34 whenever fine pitch device 30 is interposed through an alignment template 70.

Detail Description Paragraph (32):

[0070] While an alignment template 70 may be constructed of different materials and machined in different ways, an alignment template 70 should be carefully designed and fabricated to obtain and maintain proper alignment during test and burn-in test. More specifically, because it is known that the various materials utilized for fabricating the test socket and the alignment template will expand or contract during burn-in, it is important to fabricate an alignment template having a thermal co-efficient of expansion which is similar to that of the test socket and preferably out of materials having good thermal stability. Otherwise, in a worst case scenario, the semiconductor wafer could become misaligned relative to the probes of the test socket 100 during the testing process. In one embodiment of the invention, both the test socket 100 as well as the alignment template are fabricated with a polyetherimide such as Ultem.RTM. 1000 polyetherimides. Such polyetherimides provide high dielectric strength and excellent thermal stability and are therefore desirable. Additionally, alignment template 70 is laser machined to insure precision. A laser machined alignment template 70 can be used to align the semiconductor wafer 30 properly, even though there may be 5,000 or 10,000 bond pads 32 on the semiconductor wafer 30, because the overall dimensions and size of the semiconductor wafers 30 vary little, given current semiconductor wafer processing technologies. In this embodiment, the test socket 100 and alignment template 70 are both made out of Ultem.RTM. polyetherimide. The socket 100, however, is mounted on a high temperature printed circuit board 90 as is shown in FIG. 7.

Detail Description Paragraph (33):

[0071] Continuing to examine the test socket 100 of FIG. 7, there is also shown cover 80 which may be used to urge the fine pitch device 30 in a downward direction 60 and to hold the fine pitch device 30 in place during testing or burn-in test. In yet another embodiment of the invention, however, cover 80 is replaced with a thermoelectric cooler similar to that thermoelectric cooler 30 shown in FIG. 5 wherein such TEC is sized and adapted for being urged against the semiconductor wafer 30, instead of the bare die 2.

Detail Description Paragraph (34):

[0072] It is important to note that the diagram of FIG. 7 contains bond pads 32, circuit pads 36, elastomeric probes 34 and connection pads 40 which are drawn out of scale for the purposes of illustration. By way of example, some fine pitch devices, namely, semiconductor wafers, may have 5,000 such bond pads 32. Thus, the relative size of probes 34, bond pads 32 and circuit pads 36 is very small in comparison to the test socket. One skilled in the art, however, may more readily appreciate the invention by the use of such exaggerated features in the drawings. Moreover, as indicated previously, circuit pads, by way of example, the circuit pads 36 of carrier 38 of FIG. 7, may be modified in size or shape so long as permanent electrical contact is made with elastomeric probes 34 (of FIG. 7).

Detail Description Paragraph (37):

[0075] As was discussed in the background, the prior art methods of producing integrated circuits include using a wafer probe to perform simple DC and some AC testing to preliminarily eliminate 80% of all bad die 76 on semiconductor wafer 30, then to saw the wafer 30 and package the bare die 2 to create an integrated circuit prior to performing certification tests. The process of certifying an integrated circuit includes performing 100% pre-burn-in testing, then burn-in and then 100% post burn-in testing. At such point, integrated circuits having failed along the way are rejected and the rest are processed for sale or for use. With the invention herein, however, a different method may be used with respect to producing integrated circuits and other semiconductor devices formed on a semiconductor wafer, one that significantly reduces the number of steps involved in testing all of the individual integrated circuits produced from a semiconductor wafer.

Detail Description Paragraph (38):

[0076] Referring again to FIG. 1, the inventive method, for wafers, includes the step of performing wafer level burn-in tests. Specifically, because test socket 100 of FIG. 7 allows for electrical contact to be made with bond pads 32 of the fine pitch device 30 in this case, a semiconductor wafer, the individual die on the semiconductor wafer can be exercised during burn-in test. During burn-in test, a "map" is created which tracks die 76 which have failed on fine pitch device 30. The term "map" is used to represent any sort of recording of die 76 which are failed in a manner that such failed die 76 may be positively determined and separated. It is understood that, generally, the methods of performing burn-in test for bare die may be practiced with the inventive methods herein for semiconductor wafers. Thus, burn-in may be performed in an oven or with a thermoelectric cooler.

Detail Description Paragraph (39):

[0077] When fine pitch device 30 is diced post burn-in to separate die 76, the failed die 76, as indicated by the map, are separated and discarded. After failed die 76 are separated from fine pitch device 30, the remaining bare die 2 undergo complete testing to verify complete and proper performance of bare die 2. For this stage of the test process, the test sockets of FIGS. 1-6 described above may be utilized. Bare die 2 which pass this stage of the test process are known good die which may be either packaged individually as an integrated circuit or as a part of a multi-chip module. Alternatively, after the wafer level burn-in and dicing, the remaining bare die 2 may also be packaged prior to being fully tested.

Detail Description Paragraph (40):

[0078] It is worth noting that a great majority of failed die 76 will be detected during the wafer level burn-in test. Thus, because a fine pitch device 30 can contain up to several thousand die 76, the elimination of any step in the procedure of producing a known good die 2 may, in fact, save several thousand steps, one step for each die 76 on the wafer. Thus, by way of example, if a wafer contains 2,000 die 76, and 400 are die bad, these 400 bad die are identified in current manufacturing techniques by probing the wafer prior to it being diced. The 400 bad die would be subsequently discarded prior to burn-in. If 50 of the remaining 1600 die fail, they would be identified after packaging and burn-in. It can, therefore, be appreciated that using the innovative teachings of the present invention the following manufacturing steps can be eliminated: wafer probing to determine 400 bad die; 1600 pre-burn-in tests; unnecessary packaging of 50 post-burn-in bad die. Moreover, the significant cost of burning-in the individually packaged die would be substantially

reduced accordingly.

Detail Description Paragraph (41):

[0079] The foregoing disclosure and description of the invention are given as illustrative and explanatory examples of the practice of the invention. Various changes in the size, shape, combination or elements of materials can be made without departing from the spirit and scope of the invention. Changes may also be made in the method of testing bare die 2 or other fine pitch devices 30 such as semiconductor wafers, chip scale packages, printed circuit boards, ball grid array (BGA) packages, land grid array (LGA) packages and single/multiple die using probe cards. For example, the certification requirements for a die or device which is mature and known to have low failure rates may be satisfied by eliminating the burn-in test procedures. As another example, the trackings made in reference to bare die 2 also apply to testing of fine pitch devices 30 such as semiconductor wafers whether explicitly stated or not. It is understood therefore, that the invention is not limited to the specific embodiments or methods disclosed and that many modifications and changes will be apparent from the description and drawings without departing from the scope of the attached claims.

Detail Description Paragraph (42):

[0080] Moreover, it is understood that variations in the carrier and inventive methods may be made according to the type of fine pitch device being tested. By way of example, if the fine pitch device 30 of FIG. 7 is a printed circuit board, then the requirement for burn-in-test may be modified or even eliminated. As may be seen, therefore, the disclosure is directed to describing a test socket for testing fine pitch devices and is not limited merely to bare die and semiconductor wafers, but applies to any fine pitch device. Accordingly, one skilled in the art may readily appreciate changes in the physical dimensions of a carrier, and perhaps methods (as determined by test goals) to perform tests upon the specific fine pitch device. Such changes may be necessary to test fine pitch devices such as bare die, unpackaged semiconductor devices such as semiconductor wafers, as well as packaged semiconductor devices and modern circuitry for testing or carrying semiconductor devices including, for example, probe cards, bare printed circuit boards, populated circuit boards, ball grid arrays, land grid arrays, ceramic ball grid arrays and chip-scale packages.